

Deer Exclusion Effects on Understory Development Following Partial Cutting in a Pennsylvania Oak Stand

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Abstract: Forty fenced and unfenced paired plots were established in a central Pennsylvania mixed oak stand following an improvement shelterwood cut to assess the influence of deer exclusion on the establishment and development of understory vegetation during the first four years following cutting. Exclusion of deer increased the abundance and height growth of woody regeneration which consisted primarily of yellow-poplar, red maple, black birch and black gum. Few oak seedlings became established during the study in either the fenced or unfenced plots. Deer exclusion affected herbaceous composition and enhanced the abundance of woody vines and shrubs. Possible implications of deer exclusion following partial cutting on stand development and plant diversity following further overstory removal are discussed.

INTRODUCTION

Overpopulation of white-tailed deer has long been acknowledged as a problem in Pennsylvania (Frontz 1930, Leopold 1947, Marquis 1974). Protective laws and extensive clearcutting in the early 1900s led to a deer population explosion in the 1930s and 1940s (Marquis 1973). While efforts are being made to reduce the deer herd in Pennsylvania, deer densities remain high in many forested areas of the state (Pennsylvania Game Commission 1992).

Studies on the impact of deer browsing on forest regeneration following clearcutting show that height, abundance and composition of regenerating species are significantly affected (Shafer et al. 1961, Marquis and Brenneman 1981, Tilghman 1989, Trumbull et al. 1989). In northern Pennsylvania, browsing of unprotected clearcuts has led to regeneration failures characterized by inadequate stocking and dense communities of grasses, ferns, goldenrods and asters. Selective browsing in unprotected northern hardwood clearcuts has resulted in a reduction of sugar maple, pin cherry and blackberry while increasing the proportion of beech, birch, and striped maple (Marquis 1974).

Despite heavy deer browsing, most northern hardwood stands in Pennsylvania can be successfully regenerated provided there is sufficient advance regeneration of adequate size prior to the final harvest cut (Grisez and Peace 1973, Marquis 1982, Marquis and Bjorkbom 1982). In stands without adequate advanced regeneration, a series of partial cuts are recommended to establish the necessary advanced regeneration prior to final overstory removal (Marquis et al. 1991). In addition electric fencing is being used increasingly to protect regeneration from browsing in Pennsylvania (Brenneman 1988, George et al. 1991).

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While numerous studies have been conducted on the impact of deer browsing in northern hardwood stands in northern Pennsylvania, few studies of a similar nature have been conducted in oak stands in Pennsylvania. The purpose of this study was to examine the effect of deer browsing on the abundance, growth, species composition and diversity of understory vegetation following an improvement shelterwood cut in a central Pennsylvania mixed oak stand.

METHODS

Study Area

The study was conducted in a 100-year-old, even-aged, mixed oak stand on the Rothrock State Forest in the Ridge and Valley Province of central Pennsylvania. The 40 acre stand occupied a middle to lower slope position of a valley ridge with a southeast aspect. The site was moderately steep and rocky with sandstone talus predominant on the soil surface. Soil series found on this site include Andover, (fine-loamy, mixed, mesic, Typic Fragiagults), Buchanan (fine-loamy, mixed, mesic, Aquic Fragiudults) and Hazleton (loamy, skeletal, mixed, mesic, Typic Dystrochrepts). Andover and Buchanan soils contain a fragipan and are classified as poorly drained and somewhat poorly drained respectively, whereas the Hazleton soil is classified as well drained with no fragipan (Merkel et al. 1978).

In spring 1989, the stand received an improvement shelterwood cut. Cutting reduced basal area from 100 to 80 ft²/ac. Basal area measurements taken at the start of the 1990 growing season ranged from 30 to 110 ft²/ac with an average of 80 ft²/ac. Following the harvest cut, gypsy-moth related mortality reduced live basal area an additional 10 to 15% and contributed to added variation in canopy cover within the site. Basal area measurements taken in 1992 ranged from 40 to 155 ft²/ac with an average of 86 ft²/ac.

Dominant overstory tree species on the site before and after the cut were northern red, black, white and chestnut oak, yellow-poplar, and red maple. Some black gum and hickory occurred as intermediates. Few saplings and woody seedlings occurred in the stand prior to the cut. The understory contained scattered occurrences of blueberry, ferns, grasses, mosses and other perennial herbaceous and woody species. The stand was bordered to the southwest by a 5-year-old clearcut, to the northeast by a 200 acre seed-tree cut made in 1988, and to the southeast by an uncut area.

Although no direct measurements of the deer population on the site were made during the study, it is assumed the deer population was between 20 and 30 deer per square mile of forest land based on estimates by the Pennsylvania Game Commission for this portion of state. Visual sightings, evidence of browsing, and presence of deer pellets indicated the continued presence of deer on the site throughout the study. Other herbivorous and granivorous animals including gray and red squirrels, chipmunks, mice and birds were also observed on the site during the study, but their populations were not quantified.

Study Design

Forty fenced and unfenced paired plots were randomly established in the study area immediately following the improvement shelterwood cut in the spring of 1989. The fenced plots were enclosed by 4 ft. high galvanized steel hexagonal mesh (2 inch size openings) on four sides to exclude deer and other animals like rabbits but not mice or other small rodents. The exclosures, which were not covered on the top, were rectangular in shape and varied from 4 to 6 ft. wide and from 6 to 9 ft.

long. Inside each fenced area, vinyl stake flags were used to permanently mark two square grids (2.3 x 2.3 ft.) containing 5.3 ft² each. Two identical grids were established outside and adjacent to the fenced area to allow for paired comparisons of plots.

Based on surrounding stand density and extent of soil disturbance resulting from harvesting activities, the plots were classified as open, closed, or skidded. The open plots had basal areas less than 80 ft²/ac. with no soil disturbance, the closed plots had greater than 80 ft²/ac. basal area with no soil disturbance and the skidded plots generally had less than 80 ft²/ac. and exposed mineral soil following the harvest cut. There were 9 open, 20 closed, and 11 skidded plots.

Regeneration data were recorded annually in 1989, 1990 and 1992 at the end of the first, second and fourth growing season following the harvest cut. The number of tree seedlings present in each grid was recorded by species and height class. Height classes for woody species in 1989 and 1990 were <1 inch, 1 - 6 inch, 6 - 12 inch and >12 inch, and in 1992 were <1 inch, 1 - 6 inch, 6 - 12 inch, 1 - 3 ft., 3 - 5 ft., and > 5 ft. Seedlings were not permanently identified for repeated measurement; instead, independent counts were taken each year. An estimate of percent cover for herbaceous species groups and woody shrub and vine species was also made. The herbaceous vegetation categories were grasses, tall herbaceous, herbaceous, ferns, and mosses and lichens. Blackberry, grape, blueberry, and mountain laurel were recorded by species. The height and species of the tallest tree (dominant tree) on each plot were recorded in 1992. The fenced and unfenced data for all variables were obtained by averaging the recorded values for the two grids in each fenced and unfenced plot. Paired t test comparisons of mean differences were used to test the effects of fencing on seedling abundance for each species using data for all plots combined. Similar comparisons were conducted by plot type (closed, open, and skidded). Analysis of variance procedures were used to test the effect of plot type on seedling abundance.

In 1992, data were collected to quantify the effects of deer exclusion after four years of regeneration on tree, woody shrub and vine, and herbaceous species diversity. Species richness and abundance were recorded for each of the two fenced grids and the two unfenced grids used for regeneration data collection. Species richness was defined as the number of different species present. Species abundance was recorded for each species as number of stems for tree species and by visual estimates of percent cover for shrubs, vines and herbaceous species.

Species richness (number of species present) and the Shannon index ($H' = -\sum p_i \ln p_i$, where p_i = number of individuals for species i divided by the total number of individuals for all species) were used to assess species diversity. Shannon's index was calculated for each plot using trees only and using all vegetation categories. A paired t test of mean differences was used to compare the Shannon index and species richness for the fenced and unfenced treatments by plot type (closed, open or skidded) and for all plot types combined.

RESULTS

At the end of the fourth growing season following harvesting, the most frequently occurring tree species comprising the regeneration on the fenced and unfenced plots were red maple, yellow-poplar, black birch, black gum, and oak species (northern red, black, white and chestnut). Red maple was found on all fenced and unfenced plots. Birch was found on 70% of the fenced and 65% of the unfenced plots. Yellow-poplar was found on 60% of fenced and 62% of unfenced plots. Black gum was present on 35% of fenced and 20% of unfenced plots. Oak species were found on 28% of fenced and 20% of unfenced plots. Other tree species occurring on the plots included sassafras, serviceberry, hawthorn, big-toothed aspen, alternate-leaved and flowering dogwoods, black cherry, pin cherry and eastern white pine.

Throughout the study, red maple was the most abundant tree species, followed by yellow-poplar, black birch, black gum and oaks (Table 1). For some tree species, fencing resulted in an increased number of seedlings. At the end of the first growing season, the number of red maple, oak and black gum seedlings per acre averaged over all plots was significantly higher ($p < .05$) in fenced plots. All of the trees recorded the first year were less than six inches. At the end of the second growing season, only red maple had a significantly higher average total number of seedlings per acre on the fenced plots. In the different height classes, the number of red maple, yellow-poplar, black birch and black gum seedlings in the 6 - 12 inch height class and the number of black birch and black gum seedlings over 1 ft. were significantly greater in the fenced plots. After four years, only the total number of red maple and oak seedlings were significantly higher on the fenced plots. The number of red maple in the 6-12 inch, 1-3 ft. and 3-5 ft. height classes were significantly higher in the fenced plots. Yellow-poplar had significantly lower numbers on fenced plots in the <1 inch and 1-6 inch height classes, and higher numbers in the 1-3 ft., 3-5 ft. and >5 ft. height classes. The number of black birch on the fenced plots were significantly higher in the 6-12 inch, 3-5 ft. and >5 ft. height classes.

Dominant tree species varied between fenced and unfenced plots after four years of growth. In the fenced plots, black birch was the dominant species in 45% of the plots followed by red maple (25%), black gum (12%) and yellow-poplar (10%). Sassafras and aspen were dominant in <5% of fenced plots. In the unfenced plots, red maple was the dominant species in 45% of the plots followed by birch (28%), and yellow-poplar (12%). Oak species were dominant in <5% of unfenced plots. The average height of dominant trees was 4.8 ft. for fenced plots and 0.6 ft. for unfenced plots.

With the exception of yellow-poplar, plot type did not have a significant effect on the total number of tree seedlings per acre. On both fenced and unfenced plots, the total number of yellow-poplar seedlings was significantly lower on closed plots than on open or skidded plots (Table 2). Plot type did have an effect on the number of seedlings per acre for most species in the taller height classes in the fenced plots. This was particularly true for yellow-poplar and black birch where the average number of seedlings in the 1-3 ft., 3-5 ft. and >5 ft classes were substantially higher in the fenced skidded and open plots than in the fenced closed plots. The same was true for red maple in the 1-3 ft. and 3-5 ft. classes.

Herbaceous species recorded in the grass category included poverty oats grass, sedges and other monocots. The tall herbaceous plant category was mostly fireweed and snakeroot, with loosestrife, goldenrod and aster species also included in this category. The herbaceous category included teaberry, false Solomon's seal, pearly- everlasting, violets, cinquefoil, sheep sorrel and other less common dicots. Hayscented fern was common on the site with New York fern present but sparse. Woody shrubs and vines were classified by species; those found were grape, blueberry, blackberry and mountain laurel.

Paired comparisons for the mean difference between fenced and unfenced percent cover for herbaceous species showed significantly lower percent coverage in all fenced plots for grasses and ferns (Figure 1). Grasses were also lower in skidded fenced plots. Grape had a higher average percent cover on all fenced plots and on skidded fenced plots. When grape, blueberry and blackberry were combined into a woody interference category, average percent cover was higher on all fenced plots. The herbaceous category was lower in closed fenced plots only.

The Shannon index measuring diversity of all vegetation categories combined including trees averaged 1.34 for fenced plots and 1.45 for unfenced plots. Differences in the Shannon index between fenced and unfenced plots were not significant. Species richness, however, was significantly higher in the unfenced plots. Species richness averaged 6.4 species for fenced plots and 7.3 species for unfenced plots. Diversity for all species combined was not significantly different between fenced and unfenced plots when the plots were analyzed by plot type (closed, open, skidded).

Table 1. Average number of tree seedlings per acre by height class one (1989), two (1990) and four years (1992) following harvesting.

Species	Treatment	1989		1990		TOTAL	1992					TOTAL	
		< 6"	6"	< 6"	6"-12"		>12"	< 1"	1"-6"	6"-12"	1'-3'		3'-5'
Oak sp. †	Fenced	2023 •	1214	1012	0	2226	0	1720	708	0	0	0	2428 •
	Unfenced	911	708	0	0	708	0	708	0	0	0	0	708
Yel poplar	Fenced	9510	9409	2732 •	5160	17301	202	3642	1821	3845 •	3541 •	3136 •	16187
	Unfenced	6070	11534	506	5160	17200	1518 •	6880 •	3946 •	911	0	0	13255
Red maple	Fenced	42695 •	35411	5160 •	1214	41785 •	911	35512	9207 •	7892 •	1315 •	0	54837 •
	Unfenced	27924	24180	101	0	24281	1821	28228	3035	607	0	0	33691
Bl birch	Fenced	4958	3136	1922 •	3541 •	8599	2124	2832	1315 •	2428	2125 •	1821 •	12645
	Unfenced	4350	2732	202	101	3035	2125	4755	3541	2226	0	0	12647
Black gum	Fenced	2428 •	304 •	809 •	1315 •	2428	101	708	304	1113 •	202	101	2529
	Unfenced	708	1012	202	0	1214	0	1315	506	0	0	0	1821
Other ††	Fenced	607	607	405	202	1214	0	607	304	607 •	405 •	304	2227
	Unfenced	607	708	202	0	910	0	1416	0	0	0	0	1416

• Difference between fenced vs unfenced significant at $p < 0.05$.

† Oak species were black, northern red, white, and chestnut.

†† Others included sassafras, serviceberry, hawthorn, aspen, dogwood, black cherry, pin cherry and E. white pine.

Table 2.—Average number of seedlings per acre by height class for closed, open, and skidded plots in 1992.

		CLOSED n=20						
Species		<1"	1"-6"	6"-12"	1'-3'	3'-5'	>5'	TOTAL
Oak sp. †	F †††	0	2234	1416	0	0	0	3650
	U	0	1012	0	0	0	0	1012
Yel-poplar	F	405	2631	1012	1012	405	0	5465
	U	607	5868	3440	607	0	0	10522
Red maple	F	809	48969 *	9713 *	4047 *	0	0	63538 *
	U	1012	34400	1211	405	0	0	37030
Bl birch	F	3642	3035	1821	2428	1619	1012	13557
	U	2428	4856	2631	1214	0	0	11129
Black gum	F	202	1012	202	1416	202	202	3238
	U	0	2024	607	0	0	0	2631
Other ††	F	0	405	202	405	0	0	1012
	U	0	607	0	0	0	0	607

		OPEN n=9						
Species		<1"	1"-6"	6"-12"	1'-3'	3'-5'	>5'	TOTAL
Oak sp. †	F	0	735	0	0	0	0	735
	U	0	367	0	0	0	0	367
Yel-poplar	F	0	1349	2248	5846	11242	10792 **	31477
	U	1349	6745	5396	1799	0	0	15289
Red maple	F	450	19785	12141 *	18436 *	5396	0	56208 *
	U	2248	19336	4497	1349	0	0	27430
Bl birch	F	736	3311	736	4047	3679	3311	15020
	U	1840	3679	4047	2575	0	0	12141
Black gum	F	0	899	899	1349	450	0	3597
	U	0	899	899	0	0	0	1798
Other ††	F	0	405	202	405	0	0	1012
	U	0	607	0	0	0	0	607

		SKIDDED n=11						
Species		<1"	1"-6"	6"-12"	1'-3'	3'-5'	>5'	TOTAL
Oak sp. †	F	0	367	0	0	0	0	367
	U	0	367	0	0	0	0	367
Yel-poplar	F	0	7358	2943	7358 *	2207 *	2575	22441
	U	3311	8830	3679	736	0	0	16556
Red maple	F	1472	23914	5887	6254 *	368	0	37895
	U	2943	24282	5151	368	0	0	32744
Bb birch	F	736	3311	736 *	4047	3679 *	3311 *	15820
	U	1840	3679	4047	2575	0	0	12141
Black gum	F	0	0	0	368	0	0	368
	U	0	368	0	0	0	0	368
Other ††	F	0	0	736	1472 *	368	736	3311
	U	0	4899	0	0	0	0	4899

* Difference in fenced vs unfenced significant at $p < 0.05$.

† Oak species were black, northern red, white, and chestnut.

†† Others included sassafras, serviceberry, hawthorn, aspen, dogwood, black cherry, pin cherry, and E. white pine.

††† F- Fenced, U- Unfenced.

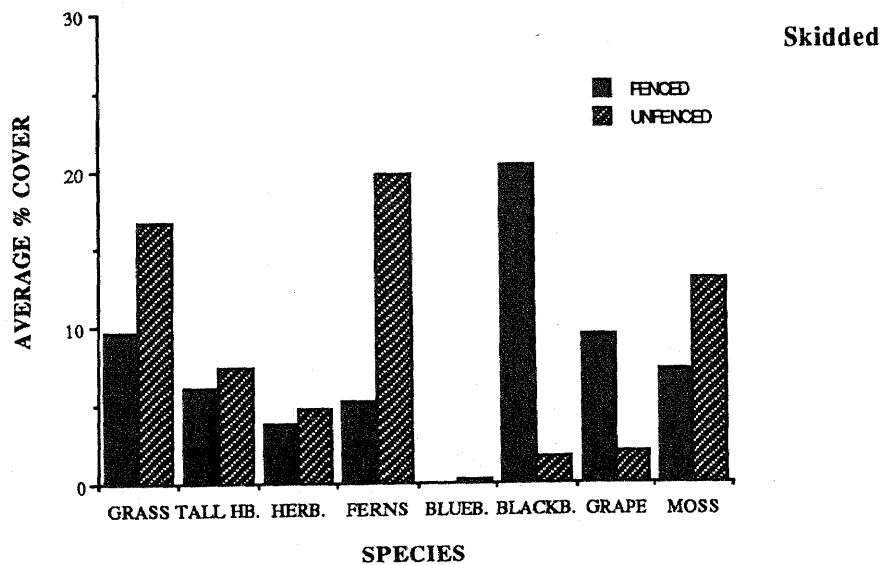
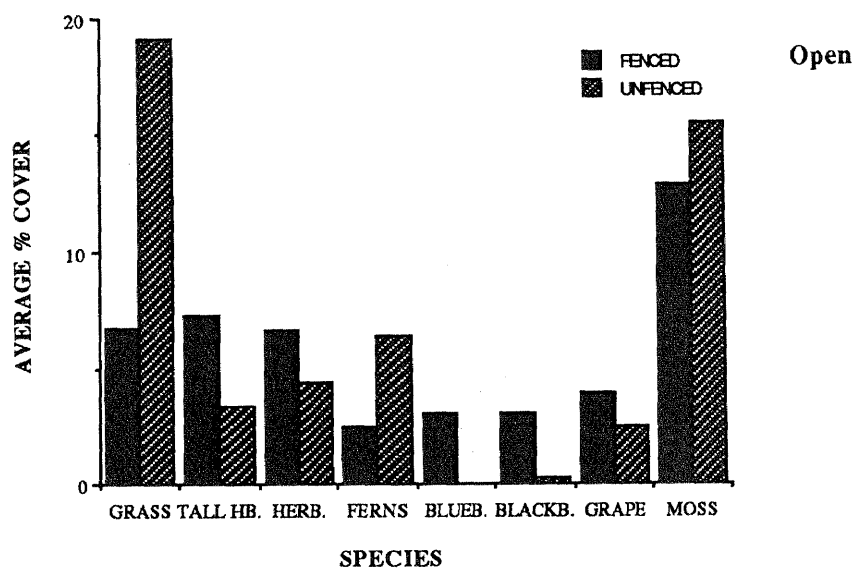
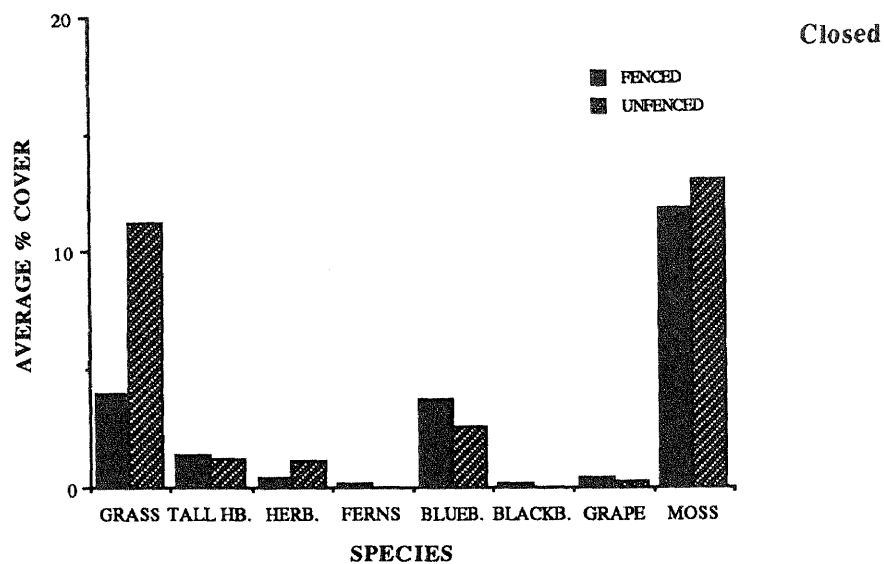


Figure 1.—Percent cover for herbaceous species on fenced and unfenced closed, open and skidded plots.

Diversity also was determined for tree regeneration alone. The Shannon index values were 0.77 for unfenced plots and 0.81 for fenced plots. Species richness averaged 3.3 species for fenced plots and 2.8 species for unfenced plots. Species richness was significantly higher for fenced plots, but the Shannon indices were not significantly different between the two treatments. Diversity for tree regeneration was not significantly different between fenced and unfenced plots when the plots were analyzed by plot type (closed, open, skidded).

DISCUSSION

Results of this study indicate that deer browsing affected the abundance, growth, species richness and diversity of regeneration in this partial cut mixed oak stand in central Pennsylvania. Elimination of deer browsing through fencing resulted in a significantly greater number of seedlings per acre for some tree species. Most notable were the increased numbers of red maple seedlings in the fenced plots. At the end of the fourth growing season, the total number of red maple seedlings per acre in the fenced plots was one and one-half times greater in the unfenced plots. The number of oak seedlings also was significantly higher in the fenced plots after four years, however, they represented only a small portion of the woody regeneration.

In addition to affecting the abundance of some tree species, elimination of deer browsing allowed for increased height growth of many species and resulted in a shift of height class distribution between the fenced and unfenced plots. With the exception of oak, all the major tree species in the regeneration advanced to heights over three feet inside the fences. This was not true outside of the fence, where no seedlings of any species exceeded 3 feet in height. This supports other studies where fencing was found to increase height growth (Marquis 1974, Shafer et al 1961, Tilghman 1989, and Trumbull et al. 1989). Tilghman's (1989) study found that in thinned Allegheny hardwood stands the tallest trees in low deer density areas were twice as tall as those in the high deer density areas.

Species richness for trees was significantly higher in fenced plots. This was likely due to the selective feeding by deer. Fencing protected those species that were more palatable. All of the tree species found occurred on both fenced and unfenced plots. However, the number of species in most cases was greater inside the fences resulting in a higher average richness. The herbaceous component of the understory differed for fenced and unfenced plots. Ferns and grasses were more abundant outside fences. Tilghman (1989) and Trumbull (1989) each found similar increases for ferns and grasses respectively, and decreases in blackberry outside of fences. Although this study didn't have a significant difference, blackberry also was more abundant in the fences. Grape also was more abundant in fenced plots due to browsing outside of fences. Inside the fences dominance by woody vegetation likely limited the presence of grasses, ferns, and other species of herbaceous vegetation.

This study also suggests a future change in the species composition of the stand. Based on the species composition of the advanced regeneration, the next stand to occupy will likely be composed of red maple, yellow-poplar, black birch, black gum and other hardwoods irrespective of whether or not the regeneration is protected from deer browsing. Oak will likely be a minor component in the next stands due to its low abundance and slow growth. Lorimer (1984) also found a replacement of oak stands by red maple in four upland oak forests in Massachusetts and New York, with understories of dense red maple and very sparse representation from the oaks. The reason(s) for the replacement of oak stands by other hardwoods is not fully understood. Abrams and Nowacki (1992) reported that repeated cutting and burning of the original oak-pine forests following European settlement increased the relative dominance of oak at least for the short term. They attributed the successional progression of the oak forests to red maple to a drastic reduction in logging

and fire in this century and noted that logging of these stands with understories dominated by red maple results in recruitment of these species into the canopy instead of the oaks. This also seems to be the case for the forest stand studied here. The browsing of white-tailed deer, the competition by herbaceous species and the reduced fire and logging in this century reduce the probability of regenerating oak stands to oak.

Results of this study indicate that the protection of partially cut oak stands in central Pennsylvania from deer browsing will likely increase the success of stand regeneration by allowing the development of advanced reproduction of sufficient size and abundance. Exclusion of deer browsing, however, will not insure the reestablishment of oak as the dominant species. It appears that in the future many of the current oaks stands will become mixed hardwood stands containing a large component of red maple.

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